CENTRAL PATH OF SOLAR ECLIPSES VISIBLE IN SOUTH AFRICA AS TOTAL OR ANNULAR ECLIPSES, DURING THE TWENTIETH CENTURY.

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During the twentieth century there will be thirty-two solar eclipses visible in South Africa, in which the amount of the sun's disc obscured will be greater than one-tenth.

In fourteen of these the amount of eclipse will be greater than one-half, and the purpose of the following paper is to give some particulars concerning them. Of the fourteen eclipses dealt with, only four are central in the Cape Colony :

Total eclipse, October 1, 1940 ;
Annular eclipse, January 14, 1945 ;
Annular eclipse, December 25, 1954 ;
Annular eclipse, January 25, 1963.

There are four other eclipses which cross South Africa between the Zambesi and Orange Rivers, and accordingly are central north of the Colony :

Annular eclipse, November 22, 1900 ;
Annular eclipse, March 17, 1923 ;
Annular eclipse, August 10, 1934 ;
Annular eclipse, April 18, 1977.

The central tracks of these eight eclipses are charted down in the accompanying map. The unbroken line indicates the path of central eclipse. Along this line, or within two or three miles on either side, the duration of eclipse—annular or total, as the case may be—will be greatest. The dotted lines mark the limits of total or annular eclipse. Beyond these limits the eclipse will be a partial one, and the further removed a place is from this zone the smaller the eclipse. In computing the positions from which the charts are drawn I have to acknowledge my indebtedness to Oppolzer's 'Syzygien-Tafeln für den Mond,' Publication der Astronomischen Gesellschaft, No. XVI., and to Dr. Mahler's 'Die Centralen Sonnenfinsternisse des XX. Jahrhunderts.'

An examination of the map indicates, generally, that all the central and southern portions of the Transvaal, the whole of the Orange Free State, except a tract of country ten miles wide bordering on the Orange River, all Griqualand West, Griqualand East, and British Bechuanaland ;

all the divisions of Cape Town, Stellenbosch, Paarl, Piquetberg, Tulbagh, Malmesbury, Hopetown, Philipstown, and Colesberg, as also nearly all Pondoland, Barkly East, Riversdale, Robertson, and Worcester, lie outside the track of total and annular eclipses.

While, on the other hand, Mashonaland, and a strip of country about 130 miles long and 20 miles wide, right in the centre of the Colony, in which, however, there are no towns of any importance, will be visited by no less than three central eclipses during the twentieth century.

The Eastern Provinces, it will be noticed, are more favoured than the Western. Thus, through the lozenge-shaped district, of which the points are Algoa Bay, Beaufort West, Burghersdorp, and Umtata River mouth, all the four central eclipses visible in the Colony pass.

A look at the map will also yield the following particulars concerning some of the principal towns in South Africa. Cape Town, Kimberley, Bloemfontein, Pretoria, Johannesburg, Durban, Pietermaritzburg, and Vryburg, lie out of the central track of all the eclipses. At these towns, accordingly, all the eclipses of the twentieth century will be partial. At Grahamstown and Port Elizabeth there will be one annular eclipse, that of December 25, 1954. The people of Grahamstown, however, may witness the total eclipse of October 1, 1940, by going out along the Fort Beaufort road about ten miles, as the southern limit of totality passes about five or six miles to the north of Grahamstown.

The people of East London, King William's Town, Fort Beaufort, Somerset East, Graaff-Reinet, Victoria West, Fraserburg, and Calvinia, and many other central towns, will have two eclipses, one total, one annular.

Three central eclipses, all annular, will pass over Fort Victoria. These are some of the general facts to be gathered from a brief examination of the map. It has been already said that fourteen eclipses will be well seen in South Africa.

The central paths of eight of these cross the continent; of the other six, four pass the continent away to the south, and therefore are visible in the Colony as partial eclipses, the amount of eclipse being greatest near the south coast. The remaining two eclipses—May 18, 1901, May 9, 1929—lie to the east of South Africa, and, accordingly, these eclipses are nearly over before sunrise in the Colony.

It remains to be said that of the four eclipses whose central line passes Africa out at sea, two come very near the coast, those of June 30, 1992, and November 3, 1994. These two eclipses, together with those central in the Colony, are the only striking eclipses as far as the Colony is concerned, during the next century.

Taking up all the fourteen eclipses, however, more in detail, the following particulars concerning them may not be lacking in interest:

(1) *Annular Eclipse of November* 22, 1900.

Soon after sunrise on the morning of November 22, 1900, there will be an annular eclipse of the sun visible in the Colony as a partial eclipse. In the Transvaal, Orange Free State, and Natal, the eclipse will be greater than in the Colony, the Transvaal being especially near the track of central eclipse. This central track lies across a portion of the country not well known as yet.

Entering Africa at a point about 100 miles south of St. Paolo de Loando at 5 h. 29 m. (G.M.T.) in the morning, it passes downwards through the Barotse country and Mashonaland, finally passing off the continent between the Island of Bazaruto and the mouth of the Sabi River, at 5 h. 54 m., thus taking twenty-five minutes only to cross Africa.

The breadth of the zone of annular eclipse is about 160 miles, and the average duration of central eclipse five and a half minutes.

The central line through Mashonaland lies midway between Fort Salisbury and Fort Victoria, both these places being within the zone of annular eclipse. The eclipse will, however, be better seen, being more central, at Fort Charter than either at Fort Salisbury or Fort Victoria. The time of greatest eclipse at Fort Charter is 5 h. 45 m. (G.M.T.).

(2) *Total Eclipse of May* 18, 1901.

On the morning of May 18, 1901, a total eclipse will pass over the southern point of Madagascar, and the islands of Bourbon and Mauritius.

The central line passes Madagascar a few miles south of Cape St. Mary; but as the zone of totality is about 130 miles broad, a portion of Madagascar will lie within it.

The central line passes almost directly over Bourbon and Mauritius, the total eclipse lasting for over three minutes at these places.

At Mauritius the eclipse will be greatest at 4 h. 3 m. morning (G.M.T.).

In Natal and the eastern districts the maximum phase will be over before sunrise. In the Western Provinces the eclipse will be quite over before sunrise; indeed, at no place in South Africa will the eclipse be a striking one.

(3) *Annular Eclipse of March* 17, 1923.

The central shadow of this eclipse enters Africa about twenty miles north of Mercury Island at 1 h. 28 m. (G.M.T.). Its direction is then east-north-east, passing between Great Namaqualand and Damaraland, through the Kalahari Desert, passing sixty miles to the south of Lake

Ngami, then through Matabeleland, about fifty miles north of Bulawayo, right through Mashonaland (almost directly over Fort Charter), crossing the Zambesi at its junction with the Shire River, and finally passing off the continent at 2 h. 16 m. (G.M.T.).

The zone of annular eclipse is 220 miles wide and within it are :

Place.	Time of Max. Eclipse.	Place.	Time of Max. Eclipse.
	G.M.T. H. M.		G.M.T. H. M.
Angra Pequina -	1 30	Fort Charter - -	2 8
Bulawayo - -	2 4	Fort Salisbury -	2 8
Fort Victoria -	2 8	Quilimane - -	2 14

In the Cape Colony the eclipses will be partial, but greater of course in the Western than in the Eastern Provinces. In the former districts the sun will be about two-thirds eclipsed, in the latter a half. The time of maximum phase at Cape Town will be 1 h. 28. m. (G.M.T.).

(4) *Total Eclipse of May* 9, 1929.

The central shadow of this eclipse touches the earth at a point 460 miles south-east of St John's River. Accordingly, at Pondoland and in Natal the maximum eclipse will take place at sunrise. In the Colony the amount of eclipse will be greatest at the sea-coast, and will amount to a little over two-thirds of the sun's disc. The eclipse will be well seen at East London.

In all the Western Provinces the maximum phase will be over before sunrise.

(5) *Annular Eclipse of August* 10, 1934.

The central shadow of this eclipse touches the continent at a point thirty miles south of Mossamedes, at 7 h. 22 m. morning (G.M.T.). Its course is then in the form of a curve almost touching the Zambesi near the Victoria Falls, passing near the town of Bulawayo, where the middle of eclipse takes place at 8 h. 13 m., and finally leaves the continent at 8 h. 34 m., at a point midway between Inhambane and the mouth of the Limpopo. In the Transvaal the eclipse will be greater than in the Colony, about 100 miles of country, forming a triangle between the Limpopo River and the Longwe Mountains, being within the zone of annular eclipse. In the Cape Colony the amount of eclipse will be about one half—greater in the eastern, less in the western districts.

At Johannesburg the time of maximum eclipse will be 8 h. 24 m. (G.M.T.).

(6) *Total Eclipse of October* 1, 1940.

This, as far as South Africa is concerned, is the most important eclipse of the twentieth century, being the only total eclipse of the sun visible in South Africa during the next hundred years.

The central shadow enters the Colony at Zout River mouth at 2 h. 6 m. (G.M.T.), and leaves the Colony at 2 h. 15 m. at a point on the coast fifteen miles north of the mouth of the Kei. Some idea may be formed of the great swiftness with which the shadow sweeps over the Colony by observing that it only takes nine minutes to cross from west to east.

Some points on the central line of total eclipse are Zout River mouth; six miles south of Calvinia; eight miles north of Fraserburg; eight miles south of Murraysburg; six miles north of Graaff-Reinet; summit of Great Winterberg; Bontebok Flats and Kei Bridge. Along this line the duration of totality will be a maximum, varying from four minutes in the west to three and a half minutes in the east.

The breadth of the zone of totality is 123 miles; that is, the eclipse will be total at all places within sixty miles on either side of the central line, but the duration of totality will be shorter the further from the central line any place is.

Within the zone of totality are the following places:

Town.	Time of Totality.	Duration of Totality.	Town.	Time of Totality.	Duration of Totality.
	G.M.T.			G.M.T.	
	H. M.	M.		H. M.	M.
Hondeklip Bay	2 6	1·5	Bedford	2 14	3·1
Clanwilliam	2 8	2·0	Tarkastadt	2 14	3·2
Calvinia	2 8	3·9	Adelaide	2 15	3·2
Sutherland	2 9	2·3	Fort Beaufort	2 15	3·2
Fraserburg	2 9	3·9	Seymour	2 15	3·4
Fraserburg Road	2 10	0·3	Queenstown	2 15	2·8
Beaufort West	2 11	3·4	Whittlesea	2 15	3·4
Victoria West	2 11	2·8	Lovedale	2 15	3·2
Murraysburg	2 11	3·7	Cathart	2 15	3·4
Richmond	2 11	2·3	Peddie	2 15	1·2
Aberdeen	2 12	3·3	Pirie	2 15	3·2
Graaff-Reinet	2 12	3·7	Stutterheim	2 16	3·4
Jansenville	2 13	2·2	King William's Town	2 16	3·0
Middleburg	2 13	2·4	Komgha	2 16	3·4
Cradock	2 13	3·5	East London	2 16	2·8
Somerset East	2 13	3·1	Butterworth	2 16	3·1
Maraisburg	2 13	2·5	Idutywa	2 16	2·8
Cookhouse	2 14	3·3			

Outside the total zone the eclipse will be of necessity partial, but all over the Colony it will be well seen, as almost at all places nine-tenths at least of the sun's disc will be obscured. It has already been stated that the city of Grahamstown is just on the borderland of totality. No doubt October 1, 1940, will be a general holiday when the day comes, so that the citizens of Grahamstown may view the only total eclipse of the century visible in the Colony.

For some of the other places the following table gives the amount and time of greatest eclipse:

Place.	Amount of Eclipse.	Time of Max. Eclipse.	Place.	Amount of Eclipse.	Time of Max. Eclipse.
		H. M.			H. M.
Cape Peninsula -	·94	2 8	Kimberley - -	·9	2 11
Piquetberg -	·97	2 8	Uitenhage and Port Elizabeth -	·97	2 13
Swellendam -	·94	2 9			
Oudtshoorn -	·95	2 10	Colesburg - -	·96	2 13
Mossel Bay -	·95	2 10	Burghersdorp -	·97	2 14
Worcester - -	·95	2 9			

(7) *Annular Eclipse of January* 14, 1945.

The central shadow of this eclipse will pass on to the earth at a point where the Division of Woodhouse is turning to the sun's light. As the South Pole is turned to the sun, and the parallels of latitude accordingly slope upwards, the shadow will move downwards through the Colony. Its path, therefore, lies through Woodhouse, Tembuland and the Transkei.

All places east of a line joining Dordrecht with Algoa Bay, have the maximum eclipse just at sunrise, as also Pondoland, Griqualand East, Basutoland, and Natal. West of this district the maximum eclipse is over before sunrise, and will therefore be of little importance. All along the central line, or, rather, within the central zone, which includes Dordrecht, Indwe, Lady Frere, Cala, Engcobo, Tsomo, Clarkebury, and Idutywa, the rare phenomenon will be witnessed of a sun rising *totally eclipsed.* For although the eclipse is theoretically annular, the ring of light seen round the moon's disc is so small, and will be so faint, that practically the eclipse is total. The duration of central eclipse is only forty-five seconds, and some idea may be formed of the velocity with which the dark shadow sweeps over the earth by observing from the tables that it takes about fifteen seconds to pass from Dordrecht to the sea, equivalent to a velocity of ten miles a second.

The zone of annular eclipse is narrow, being only forty miles wide.

(8) *Annular Eclipse of December* 25, 1954.

This annular eclipse crosses the Colony from Hondeklip Bay to Algoa Bay. The central shadow enters the Colony at Hondeklip Bay at 5 h. 55 m., morning (G.M.T.), passes eight miles to the north of Calvinia, seven miles to the south of Fraserburg, four miles to the north of Beaufort West, and finally passes off the Colony at Bird Island at 6 h. 6 m., taking eleven minutes to cross the Colony.

The breadth of the zone of annular eclipse is 180 miles; that is, within ninety miles on either side of the central line the sun will be annularly eclipsed. Beyond this zone the eclipse will be partial, and will be well seen all over the Colony.

Along the central line the duration of annular eclipse will be six minutes on an average.

The further any place is from this central line, the shorter will be duration of central eclipse.

The following places lie within the zone of annular eclipse:

Place.	Distance from Central Line.	Time of Greatest Eclipse.	Place.	Distance from Central Line.	Time of Greatest Eclipse.
	Miles.	H. M.		Miles.	H. M.
Port Nolloth -	55	5 54	Humansdorp -	50	6 4
Ookiep - -	58	5 55	Cradock - -	87	6 5
Clanwilliam -	75	5 56	Somerset East -	54	6 5
Calvinia - -	8	5 57	Uitenhage - -	17	6 6
Fraserburg -	7	5 58	Bedford - -	65	6 6
Carnarvon - -	83	5 59	Port Elizabeth -	25	6 7
Victoria West -	73	6 1	Fort Beaufort -	75	6 7
Beaufort West -	4	6 1	Grahamstown -	38	6 7
Prince Albert -	65	6 1	Lovedale - -	76	6 8
Oudtshoorn -	83	6 1	Port Alfred -	28	6 8
Murraysburg -	55	6 2	King Wm.'s Town	87	6 8
Graaff-Reinet -	60	6 2	East London -	89	6 9

(9) *Annular Eclipse of January* 25, 1963.

This annular eclipse crosses South Africa from Danger Point to St. Lucia Lake. The breadth of the zone of annular eclipse is only twenty-eight miles; the eclipse is therefore just on the border of totality.

Indeed, so narrow will the ring of light round the moon's disc be, that it is probable it will be quite, or nearly, invisible to the naked eye. The eclipse is therefore practically total.

Points within the central zone are:

Place.	Distance from Central Line.	Time of Greatest Eclipse.
	Miles.	G.M.T. H. M.
Danger Point - - - -	5	2 45
Swellendam - - - -	2	2 47
Ladismith - - - - -	7	2 49
Prince Albert - - - -	0	2 50
Middleburg - - - -	8	2 54
Steynsburg - - - - -	3	2 55
Burghersdorp - - - -	4	2 55
Aliwal North - - - -	8	2 56
Herschel - - - - -	2	2 57
Giant's Kop - - - -	4	2 59
Greytown, Natal - - -	8	3 1
Ulundi, Zululand - - -	5	3 2

The duration of annular eclipse along the central line will be only forty seconds.

At Cape Town, Stellenbosch, Paarl, Caledon, Bredasdorp, Mossel Bay, Oudtshoorn, Beaufort West, Murraysburg, Graaff-Reinet, Cradock Molteno, Weenen, and Pietermaritzburg, the eclipse will be well seen, more than nine-tenths of the sun's disc being obscured.

(10) *Total Eclipse of November* 12, 1966.

The central line of this eclipse passes about 550 miles south of Cape Colony. Along the south coast the amount of eclipse will be seven-tenths, being greatest along the coast from Port Elizabeth to East London.

At the Orange River the eclipse will be about one half. The eclipse is greatest in the Colony between four o'clock and a quarter past four.

(11) *Annular Eclipse of April* 18, 1977.

This annular eclipse passes over the least-known portions of South Africa during the afternoon of April 18, 1977.

The central line touches South Africa at a point 150 miles north of Walfish Bay. It then passes north-east through North Damaraland, Ovampoland ; crosses the Zambesi at Libonta in the Barotse country ; passes between Lake Moero and Lake Bangweolo ; crosses the Stevenson Road between Lake Tanganyika and Lake Nyassa, and finally passes off the continent a little north of Zanzibar.

At Cape Town the sun will be scarcely half eclipsed, and in the eastern provinces and in Natal the eclipse will be even smaller.

Nearer the Orange River the eclipse will, of course, be greater; but in no part of the Colony will it be a striking one.

(12) *Total Eclipse of June* 30, 1992.

The central line of this total eclipse passes in a south-easterly direction about 350 miles out from the Cape of Good Hope. The eclipse is therefore greatest at the Cape Peninsula, amounting to about eight-tenths of the sun's disc.

In the eastern districts the amount of eclipse is one half. The time of maximum eclipse at Cape Town is 1 h. 33 m., afternoon (G.M.T.).

(13) *Total Eclipse of November* 3, 1994.

This total eclipse passes almost parallel to the south coast of the Colony, at a distance of 200 miles.

The northern limit of totality comes nearest to the coast at about 150 miles south of Cape St. Francis. The eclipse will therefore be greatest at the coast towns. At Port Elizabeth and East London only a tenth of the sun's disc will be visible.

At Cape Town the amount of eclipse will be slightly less. In the districts bordering on the Orange River two-thirds of the sun will be obscured. At Port Elizabeth the greatest eclipse takes place at 3 h. 6 m. (G.M.T.).

(14) *Total Eclipse of August* 11, 1999.

This total eclipse will pass about 650 miles south-west of Cape Agulhas. In the South-western Provinces the amount of eclipse will be about two-thirds. In the Eastern Provinces the amount will be less than one half. The eclipse will be greatest in the Colony about noon (G.M.T.).

APPENDIX.

THE following tables give the direction of the eight eclipses—seven annular and one total—already referred to as being central in South Africa.

In the first column is given the hour angle of the sun; in the second, the duration of central eclipse; and in the others the northern and southern limits and central line of total or annular eclipse.

As the hour angle of the sun is the apparent local time, the Greenwich mean time of central eclipse can easily be found by first reducing

apparent local time to mean local time, and then, the longitude being known, to Greenwich mean time.

The duration of annular eclipse also indicates, roughly, the breadth of the annular ring round the moon, for as the moon, on an average, moves through its own diameter in sixty minutes, the ratio—

Duration of eclipse : sixty minutes

will indicate the ratio of the annular ring to the whole disc.

The central path of the four most important eclipses,

1940, October 1,
1945, January 14,
1954, December 25,
1963, January 25,

have been computed from Oppolzer's 'Syzygien Tafeln für den Mond;' and the central path of the other four,

1900, November 22,
1923, March 17,
1934, August 10,
1977, April 18,

from constants given in Dr. Mahler's 'Die Centralen Sonnenfinsternisse des XX Jahrhunderts.'

The duration of eclipse, and the northern and southern limits of central eclipse, have been taken direct from Dr. Mahler's work, as it was not considered worth while re-computing them from Oppolzer's tables. The limits of central eclipse, and accordingly the duration of central eclipse, cannot be known with the same accuracy as the central line, inasmuch as they depend more upon the relative parallaxes and relative angular diameters of the sun and moon.

At the commencement of each set of positions are the formulæ used in computing the central line of total or annular eclipse.

In them, h = sun's hour angle.
ϕ = geographical latitude.
λ = longitude.

Annular Eclipse, November 22, 1900.

CENTRAL LINE.

$$\text{Tan A} = 9{\cdot}5878 \sin (251^\circ{\cdot}26 + \text{h})$$

$$\text{Sin} (\phi_1 - \text{A}) = 9{\cdot}3861_n \cos \text{A}$$

$$\phi = \phi_1 + 0^\circ{\cdot}096 \sin 2\phi_1$$

$$\lambda = \text{h} + 66^\circ{\cdot}59 + [0{\cdot}4968] \sin \phi_1 + [1{\cdot}4600] \cos (87^\circ{\cdot}71 + \text{h}) \cos \phi_1$$

Hour Angle.	Duration.	Northern Limits.		Central Line.		Southern Limits.	
		ϕ	λ	ϕ	λ	ϕ	λ
	m.	° ′	° ′	° ′	° ′	° ′	° ′
−83°·22	4·9	− 8 12	11 24 E	− 9 28	11 14 E	− 10 46	11 2 E
82·22	4·9	8 35	12 17	9 52	12 7	11 9	11 56
81·22	4·9	8 59	13 11	10 15	13 1	11 32	12 50
80·22	5·0	9 23	14 4	10 38	13 54	11 55	13 43
79·22	5·0	9 46	14 57	11 2	14 46	12 18	14 35
78·22	5·0	10 10	15 49	11 25	15 38	12 35	15 26
77·22	5·0	10 33	16 41	11 48	16 29	13 4	16 18
76·22	5·1	10 56	17 32	12 11	17 20	13 28	17 9
75·22	5·1	11 20	18 22	12 35	18 11	13 50	17 59
74·22	5·1	11 44	19 12	12 59	19 0	14 13	18 49
73·22	5·1	12 8	20 1	13 22	19 49	14 36	19 37
72·22	5·2	12 32	20 50	13 45	20 38	14 59	20 25
71·22	5·2	12 56	21 38	14 8	21 26	15 22	21 13
70·22	5·2	13 20	22 25	14 32	22 13	15 44	22 0
69·22	5·2	13 43	23 12	14 55	23 0	16 8	22 47
68·22	5·3	14 7	23 59	15 18	23 47	16 31	23 33
67·22	5·3	14 30	24 45	15 41	24 32	16 53	24 19
66·22	5·3	14 53	25 31	16 4	25 18	17 16	25 5
65·22	5·3	15 16	26 16	16 27	26 3	17 38	25 50
64·22	5·4	15 39	27 0	16 50	26 47	18 1	26 34
63·22	5·4	16 2	27 44	17 13	27 31	18 24	27 18
62·22	5·4	16 25	28 28	17 35	28 15	18 46	28 1
61·22	5·4	16 48	29 11	17 58	28 58	19 8	28 44
60·22	5·5	17 10	29 53	18 20	29 41	19 31	29 27
59·22	5·5	17 33	30 35	18 43	30 23	19 53	30 9
58·22	5·5	17 56	31 17	19 5	31 5	20 14	30 51
57·22	5·5	18 18	31 59	19 27	31 46	20 36	31 32
56·22	5·6	18 40	32 41	19 49	32 27	20 58	32 14
55·22	5·6	19 2	33 22	20 10	33 8	21 19	32 55
54·22	5·6	19 24	34 2	20 32	33 48	21 40	33 35
53·22	5·6	19 45	34 42	20 53	34 28	22 1	34 5
52·22	5·7	20 7	35 22	21 14	35 8	22 21	34 55
51·22	5·7	20 29	36 1	21 35	35 47	22 41	35 34

Annular Eclipse, March 17, 1923.

CENTRAL LINE.

$\text{Tan A} = 9{\cdot}5056 \sin (354^\circ{\cdot}19 + \text{h})$

$\text{Sin} (\phi_1 - \text{A}) = 9{\cdot}7559_n \cos \text{A}$

$\phi = \phi_1 + 0^\circ{\cdot}096 \sin 2\phi_1$

$\lambda = \text{h} + 351^\circ{\cdot}05 + [0{\cdot}9507_n] \sin \phi_1 + [1{\cdot}4502] \cos (90^\circ{\cdot}52 + \text{h}) \cos \phi_1$

Hour Angle.	Duration.	Northern Limits.		Central Line.		Southern Limits.	
		ϕ	λ	ϕ	λ	ϕ	λ
	m.	° ′	° ′	° ′	° ′	° ′	° ′
28·04	9·1	− 25 41	10 48 E	− 27 25	11 13 E	− 29 9	11 56 E
29·04	9·1	25 22	11 20	27 6	11 45	28 50	12 10
30·04	9·0	25 3	11 53	26 47	12 18	28 31	12 44
31·04	9·0	24 44	12 26	26 28	12 50	28 12	13 17
32·04	8·9	24 26	12 58	26 9	13 23	27 53	13 50
33·04	8·9	24 8	13 31	25 51	13 56	27 35	14 23
34·04	8·8	23 50	14 4	25 32	14 29	27 16	14 56
35·04	8·8	23 32	14 37	25 14	15 3	26 58	15 30
36·04	8·7	23 14	15 11	24 56	15 37	26 40	16 4
37·04	8·7	22 57	15 44	24 38	16 10	26 22	16 38
38·04	8·6	22 40	16 18	24 21	16 44	26 4	17 12
39·04	8·6	22 22	16 52	24 4	17 19	25 46	17 46
40·04	8·5	22 5	17 27	23 46	17 53	25 29	18 21
41·04	8·5	21 48	18 1	23 29	18 28	25 12	18 56
42·04	8·4	21 32	18 36	23 13	19 4	24 55	19 31
43·04	8·4	21 15	19 11	22 56	19 39	24 38	20 7
44·04	8·3	20 58	19 47	22 39	20 15	24 21	20 43
45·04	8·3	20 42	20 24	22 23	20 52	24 5	21 20
46·04	8·2	20 26	21 1	22 7	21 28	23 49	21 56
47·04	8·2	20 11	21 37	21 52	22 5	23 34	22 34
48·04	8·1	19 56	22 15	21 36	22 42	23 18	23 11
49·04	8·1	19 40	22 52	21 20	23 20	23 2	23 49
50·04	8·0	19 25	23 30	21 5	23 58	22 47	24 26
51·04	7·9	19 11	24 8	20 50	24 36	22 32	25 5
52·04	7·9	18 56	24 47	20 36	25 15	22 17	25 44
53·04	7·8	18 42	25 27	20 22	25 55	22 2	26 24
54·04	7·7	18 29	26 7	20 8	26 34	21 49	27 4
55·04	7·7	18 15	26 47	19 54	27 14	21 35	27 44
56·04	7·6	18 1	27 28	19 40	27 55	21 21	28 25
57·04	7·5	17 48	28 9	19 27	28 37	21 8	29 6
58·04	7·5	17 35	28 50	19 14	29 18	20 55	29 47
59·04	7·4	17 23	29 32	19 2	30 0	20 43	30 29
60·04	7·3	17 11	30 15	18 50	30 43	20 31	31 11
61·04	7·3	16 59	30 58	18 38	31 26	20 19	31 55
62·04	7·2	16 48	31 42	18 26	32 9	20 7	32 38
63·04	7·1	16 37	32 26	18 14	32 53	19 55	33 22
64·04	7·0	16 26	33 10	18 3	33 38	19 44	34 7
65·04	7·0	16 15	33 55	17 53	34 23	19 33	34 52
66·04	6·9	16 5	34 41	17 43	35 8	19 23	35 37
67·04	6·8	15 55	35 27	17 33	35 55	19 13	36 23
68·04	6·7	15 45	36 14	17 23	36 42	19 2	37 10
69·04	6·6	15 35	37 1	17 13	37 29	18 52	37 57
70·04	6·6	15 26	37 49	17 4	38 16	18 43	38 45
71·04	6·5	15 16	38 37	16 55	39 5	18 34	39 34
72·04	6·4	15 9	39 26	16 46	39 54	18 26	40 22
73·04	6·4	15 1	40 16	16 38	40 43	18 18	41 11
74·04	6·3	14 53	41 6	16 30	40 33	18 0	42 0
75·04	6·2	14 46	41 57	16 32	42 23	17 42	42 50

CENTRAL LINE.

$\text{Tan A} = 9{\cdot}7250 \sin (147°{\cdot}81 + \text{h})$

$\text{Sin} (\phi_1 - \text{A}) = 9{\cdot}8918_n \cos \text{A}$

$\phi = \phi_1 + 0°{\cdot}096 \sin 2\phi_1$

$\lambda = \text{h} + 51°{\cdot}82 + [1{\cdot}0507] \sin \phi_1 + [1{\cdot}4374] \cos (96°{\cdot}66 + \text{h}) \cos \phi_1$

Hour Angle.	Duration.	Northern Limits.		Central Line.		Southern Limits.	
		ϕ	λ	ϕ	λ	ϕ	λ
	m.						
−64°35	5·5	−14 26	7 6 E	−15 50	6 41 E	−17 14	6 15 E
63·35	5·5	14 22	7 52	15 46	7 27	17 10	7 2
62·35	5·5	14 19	8 37	15 43	8 13	17 7	7 47
61·35	5·6	14 16	9 22	15 40	8 58	17 4	8 32
60·35	5·6	14 15	10 6	15 38	9 42	17 1	9 17
59·35	5·6	14 14	10 50	15 37	10 26	17 0	10 1
58·35	5·7	14 14	11 33	15 36	11 9	16 59	10 44
57·35	5·7	14 14	12 16	15 36	11 52	16 59	11 28
56·35	5·7	14 15	12 58	15 37	12 34	16 59	12 10
55·35	5·7	14 16	13 39	15 38	13 16	17 0	12 52
54·35	5·8	14 19	14 20	15 40	13 57	17 1	13 33
53·35	5·8	14 21	15 0	15 42	14 37	17 4	14 14
52·35	5·8	14 25	15 40	15 46	15 17	17 7	14 54
51·35	5·9	14 29	16 19	15 49	15 56	17 10	15 34
50·35	5·9	14 34	16 58	15 54	16 35	17 14	16 13
49·35	5·9	14 40	17 37	15 59	17 14	17 19	16 52
48·35	6·0	14 46	18 15	16 5	17 52	17 25	17 30
47·35	6·0	14 52	18 52	16 11	18 29	17 31	18 7
46·35	6·0	15 0	19 28	16 19	19 7	17 38	18 44
45·35	6·1	15 8	20 5	16 26	19 43	17 46	19 21
44·35	6·1	15 17	20 40	16 35	20 19	17 55	19 57
43·35	6·1	15 26	21 16	16 44	20 55	18 3	20 33
42·35	6·1	15 36	21 51	16 53	21 30	18 13	21 8
41·35	6·1	15 47	22 26	17 4	22 5	18 23	21 44
40·35	6·2	15 58	23 0	17 15	22 39	18 34	22 18
39·35	6·2	16 10	23 34	17 27	23 13	18 45	22 52
38·35	6·2	16 23	24 7	17 40	23 47	18 57	23 26
37·35	6·2	16 37	24 40	17 52	24 20	19 10	23 59
36·35	6·3	16 50	25 13	18 6	24 53	19 23	24 32
35·35	6·3	17 5	25 45	18 20	25 25	19 38	25 5
34·35	6·3	17 19	26 17	18 35	25 58	19 53	25 37
33·35	6·3	17 34	26 49	18 50	26 29	20 9	26 9
32·35	6·3	17 50	27 20	19 6	27 1	20 26	26 41
31·35	6·4	18 7	27 52	19 23	27 32	20 44	27 12
30·35	6·4	18 23	28 23	19 41	28 4	21 1	27 43
29·35	6·4	18 41	28 53	19 59	28 34	21 19	28 14
28·35	6·4	18 59	29 23	20 18	29 5	21 38	28 45
27·35	6·4	19 18	29 54	20 37	29 35	21 58	29 16
26·35	6·5	19 37	30 24	20 56	30 5	22 18	29 46
25·35	6·5	19 57	30 53	21 17	30 35	22 38	30 15
24·35	6·5	20 17	31 23	21 38	31 5	23 0	30 45
23·35	6·5	20 39	31 52	22 0	31 34	23 22	31 15
22·35	6·5	21 1	32 22	22 22	32 4	23 44	31 44
21·35	6·6	21 23	32 51	22 44	32 33	24 7	32 13
20·35	6·6	21 46	33 19	23 8	33 2	24 31	32 42
19·35	6·6	22 9	33 48	23 32	33 31	24 55	33 11
18·35	6·6	22 53	34 16	23 56	33 59	25 20	33 39
17·35	6·6	23 37	34 44	24 21	34 27	25 45	34 7

Total Eclipse, October 1, 1940.

CENTRAL LINE.

$$\text{Tan A} = 9{\cdot}5096 \sin (190°{\cdot}14 + \text{h})$$
$$\text{Sin} (\phi_1 - \text{A}) = 9{\cdot}4372 \cos \text{A}$$
$$\phi = \phi_1 + 0°{\cdot}096 \sin 2\,\phi_1$$
$$\lambda = \text{h} + 346°{\cdot}38 + [0{\cdot}88733] \sin \phi_1 + [1{\cdot}38901] \cos (88°{\cdot}97 + \text{h}) \cos \phi$$

Hour Angle.	Duration.	Northern Limits.		Central Line.		Southern Limits.	
		ϕ	λ	ϕ	λ	ϕ	λ
	m.						
50°14	4·2	−30 6	16 37 E	−31 2	16 40 E	−31 59	16 42 E
51·14	4·2	30 15	17 23	31 11	17 26	32 7	17 29
52·14	4·1	30 23	18 10	31 19	18 13	32 14	18 16
53·14	4·1	30 30	18 56	31 26	19 0	32 21	19 3
54·14	4·0	30 38	19 43	31 33	19 47	32 28	19 50
55·14	4·0	30 45	20 31	31 40	20 34	32 35	20 37
56·14	3·9	30 52	21 19	31 47	21 22	32 42	21 25
57·14	3·8	30 59	22 7	31 54	22 11	32 49	22 14
58·14	3·8	31 6	22 55	32 0	22 59	32 54	23 2
59·14	3·7	31 12	23 43	32 5	23 48	32 59	23 50
60 14	3·7	31 18	24 32	32 11	24 37	33 5	24 39
61·14	3·6	31 23	25 22	32 17	25 26	33 10	25 29
62·14	3·6	31 29	26 12	32 22	26 16	33 14	26 20
63·14	3·5	31 34	27 1	32 26	27 7	33 19	27 10
64·14	3·5	31 38	27 52	32 31	27 57	33 23	28 1
65·14	3·5	31 43	28 42	32 35	28 47	33 27	28 52
66·14	3·4	31 47	29 33	32 39	29 38	33 31	29 43
67·14	3·4	31 51	30 24	32 43	30 30	33 35	30 35
68·14	3·3	31 55	31 16	32 47	31 22	33 38	31 26
69·14	3·3	31 59	32 8	32 50	32 14	33 40	32 19
70·14	3·3	32 3	33 1	32 52	33 7	33 43	33 12

Annular Eclipse, January 14, 1945.

CENTRAL LINE.

$$\text{Tan A} = 9{\cdot}6027 \sin (281°{\cdot}51 + \text{h})$$
$$\text{Sin} (\phi_1 - \text{A}) = 9{\cdot}7249_n \cos \text{A}$$
$$\phi = \phi_1 + 0°{\cdot}096 \sin 2\,\phi_1$$
$$\lambda = \text{h} + 106°{\cdot}80 + [0{\cdot}2694_n] \sin \phi_1 + [1{\cdot}4317] \cos (91°{\cdot}55 + \text{h}) \cos \phi_1$$

Hour Angle.	Duration.	Northern Limits.		Central Line.		Southern Limits.	
		ϕ	λ	ϕ	λ	ϕ	λ
	m.						
−103°65	0·9	−30 58	26 47 E	−31 18	26 43 E	−31 38	26 38 E
102·65	0·9	31 23	27 47	31 42	27 43	32 1	27 38
101·65	0·9	31 47	28 46	32 6	28 41	32 25	28 37
100·65	0·9	32 12	29 44	32 30	29 38	32 48	29 36
99·65	0·9	32 36	30 43	32 53	30 38	33 11	30 34
98·65	0·9	33 0	31 41	33 17	31 37	33 34	31 32
97·65	0·9	33 23	32 38	33 40	32 34	33 57	32 30
96·65	0·9	33 47	33 35	34 4	33 31	34 20	33 27
95·65	0·9	34 11	34 31	34 27	34 27	34 43	34 23
94·65	0·9	34 34	35 27	34 50	35 23	35 7	35 19
93·65	0·9	34 57	36 22	35 14	36 19	35 31	36 15

Annular Eclipse, December 25, 1954.

CENTRAL LINE.

$$\text{Tan A} = 9{\cdot}65797 \sin (287{\cdot}31 + \text{h})$$
$$\text{Sin} (\phi_1 - \text{A}) = 9{\cdot}45668 \cos \text{A}$$
$$\phi = \phi_1 + 0^\circ{\cdot}096 \sin 2\phi_1$$
$$\lambda = \text{h} + 65^\circ\,68 + [0{\cdot}51674_n] \sin \phi_1 + [1{\cdot}46332] \cos (92^\circ{\cdot}82 + \text{h}) \cos \phi_1$$

Hour Angle.	Duration.	Northern Limits.		Central Line.		Southern Limits.	
		ϕ	λ	ϕ	λ	ϕ	λ
	m.	° ′	° ′	° ′	° ′	° ′	° ′
−78·17	5·8	−27 22	14 0 E	−28 48	13 45 E	−30 14	13 29 E
77·17	5·8	27 44	14 49	29 9	14 34	30 35	14 19
76·17	5·8	28 5	15 38	29 30	15 23	30 55	15 7
75·17	5·9	28 26	16 26	29 50	16 11	31 15	15 55
74·17	5·9	28 47	17 14	30 11	16 59	31 35	16 43
73·17	5·9	29 7	18 2	30 31	17 46	31 55	17 31
72·17	5·9	29 27	18 49	30 50	18 34	32 14	18 18
71·17	6·0	29 46	19 35	31 9	19 21	32 32	19 5
70·17	6·0	30 5	20 22	31 28	20 7	32 51	19 52
69·17	6·0	30 24	21 8	31 46	20 53	33 9	20 38
68·17	6·0	30 43	21 55	32 4	21 40	33 26	21 24
67·17	6·1	31 1	22 41	32 22	22 25	33 44	22 10
66·17	6·1	31 19	23 26	32 40	23 10	34 1	22 55
65·17	6·1	31 36	24 10	32 57	23 55	34 17	23 40
64·17	6·2	31 53	24 55	33 14	24 40	34 34	24 24
63·17	6·2	32 10	25 39	33 30	25 24	34 50	25 8
62·17	6·2	32 27	26 23	33 46	26 8	35 5	25 53
61·17	6·3	32 43	27 7	34 2	26 52	35 21	26 37
60·17	6·3	32 59	27 51	34 17	27 36	35 36	27 20
59·17	6·3	33 14	28 34	34 32	28 19	35 51	28 4
58·17	6·4	33 29	29 17	34 47	29 2	36 5	28 47

Annular Eclipse, January 25, 1963.

CENTRAL LINE.

$$\text{Tan A} = 9{\cdot}57897 \sin (294^\circ{\cdot}04 + \text{h})$$
$$\text{Sin} (\phi_1 - \text{A}) = 9{\cdot}71839 \cos \text{A}$$
$$\phi = \phi_1 + 0^\circ{\cdot}096 \sin 2\,\phi_1$$
$$\lambda = \text{h} + 338^\circ{\cdot}69 + [0{\cdot}56628] \sin 2\,\phi_1 + [1{\cdot}42982] \cos (92^\circ{\cdot}72 + \text{h}) \cos \phi_1$$

Hour Angle.	Duration.	Northern Limits.		Central Line.		Southern Limits.	
		ϕ	λ	ϕ	λ	ϕ	λ
	m.						
54·97	0·5	− 35 32	17 17 E	− 35 40	17 18 E	− 35 47	17 20 E
55·97	0·5	35 9	17 59	35 18	18 0	35 26	18 2
56·97	0·5	34 47	18 40	34 56	18 42	35 5	18 44
57·97	0·5	34 25	19 22	34 35	19 25	34 44	19 27
58·97	0·5	34 3	20 5	34 13	20 7	34 22	20 10
59·97	0·5	33 41	20 48	33 51	20 50	34 1	20 52
60·97	0·5	33 19	21 31	33 29	21 33	33 38	21 55
61·97	0·6	32 56	22 14	33 7	22 16	33 16	22 19
62·97	0·6	32 33	22 57	32 44	23 0	32 55	23 3
63·97	0·6	32 10	23 41	32 22	23 44	32 32	23 47
64·97	0·6	31 47	24 26	31 59	24 28	32 9	24 31
65·97	0·6	31 25	25 10	31 37	25 13	31 47	25 16
66·97	0·6	31 2	25 55	31 14	25 58	31 25	26 1
67·97	0·6	30 38	26 41	30 50	26 44	31 2	26 47
68·97	0·6	30 15	27 26	30 28	27 30	30 39	27 33
69·97	0·7	29 52	28 13	30 5	28 16	30 16	28 19
70·97	0·7	29 28	28 59	29 42	29 2	29 53	29 5
71·97	0·7	29 5	29 46	29 19	29 49	29 31	29 52
72·97	0·7	28 41	30 33	28 55	30 36	29 8	30 39
73·97	0·7	28 18	31 20	28 32	31 24	28 45	31 27
74·97	0·7	27 55	32 8	28 9	32 12	28 22	32 16
75·97	0·7	27 31	32 57	27 46	33 1	27 59	33 4
76·97	0·8	27 7	33 46	27 22	33 50	27 37	33 53
77·97	0·8	26 44	34 35	26 59	34 39	27 13	34 43
78·97	0·8	26 21	35 24	26 35	35 28	26 49	35 33
79·97	0·8	25 58	36 13	26 11	36 17	26 25	36 23

Annular Eclipse, April 18, 1977.

CENTRAL LINE.

$$\text{Tan A} = 9{\cdot}5275 \sin (34^\circ{\cdot}86 + \text{h})$$
$$\text{Sin} (\phi_1 - \text{A}) = 9{\cdot}6229_n \cos \text{A}$$
$$\phi = \phi_1 + 0^\circ{\cdot}096 \sin 2\phi_1$$
$$\lambda = \text{h} + 21^\circ{\cdot}80 + [0.8755_n] \sin \phi_1 + [1{\cdot}4532] \cos (87^\circ{\cdot}08 + \text{h}) \cos \phi_1$$

Hour Angle.	Duration.	Northern Limits.		Central Line.		Southern Limits.	
		ϕ	λ	ϕ	λ	ϕ	λ
	m.						
−23°·48	6·3	−19° 59′	12° 45′ E	−21° 2′	12° 48′ E	−22° 5′	12° 52′ E
22·48	6·3	19 38	13 19	20 41	13 22	21 45	13 26
21·48	6·3	19 17	13 52	20 20	13 55	21 25	13 59
20·48	6·3	18 57	14 25	20 0	14 29	21 4	14 32
19·48	6·3	18 37	14 58	19 40	15 2	20 43	15 5
18·48	6·4	18 17	15 31	19 19	15 35	20 23	15 39
17·48	6·4	17 57	16 3	18 59	16 7	20 3	16 11
16·48	6·4	17 38	16 35	18 40	16 39	19 43	16 43
15·48	6·4	17 18	17 6	18 20	17 11	19 23	17 16
14·48	6·5	16 58	17 38	18 0	17 43	19 3	17 47
13·48	6·5	16 38	18 9	17 40	18 14	18 43	18 19
12·48	6·5	16 19	18 40	17 20	18 45	18 23	18 50
11·48	6·5	16 0	19 11	17 1	19 16	18 4	19 22
10·48	6·6	15 41	19 41	16 42	19 47	17 44	19 52
9·48	6·6	15 22	20 11	16 23	20 17	17 25	20 22
8·48	6·6	15 2	20 41	16 4	20 47	17 6	20 53
7·48	6·6	14 43	21 11	15 44	21 17	16 47	21 23
6·48	6·6	14 25	21 40	15 26	21 47	16 28	21 53
5·48	6·7	14 7	22 10	15 7	22 17	16 9	22 23
4·48	6·7	13 49	22 40	14 49	22 46	15 51	22 53
3·48	6·7	13 30	23 9	14 31	23 16	15 32	23 23
2·48	6·7	13 12	23 38	14 13	23 45	15 14	23 52
1·48	6·7	12 54	24 7	13 55	24 14	14 56	24 23
−0·48	6·8	12 37	24 35	13 37	24 43	14 38	24 51
+0·52	6·8	12 19	25 4	13 19	25 12	14 21	25 20
1·52	6·8	12 2	25 33	13 2	25 41	14 4	25 50
2·52	6·8	11 46	26 2	12 46	26 10	13 47	26 19
3·52	6·8	11 29	26 31	12 29	26 39	13 30	26 47
4·52	6·9	11 12	26 59	12 12	27 8	13 13	27 16
5·52	6·9	10 55	27 27	11 56	27 36	12 56	27 45
6·52	6·9	10 40	27 56	11 40	28 5	12 41	28 14
7·52	6·9	10 24	28 24	11 25	28 34	12 25	28 43
8·52	6·9	10 8	28 52	11 9	29 2	12 10	29 11
9·52	6·9	9 52	29 20	10 53	29 30	11 54	29 39
10·52	7·0	9 37	29 47	10 38	29 57	11 40	30 7